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EXCITATION OF SHORT-PERIODICAL OSCILLATIONS OF THE EARTH'S MAGNETIC FIELD DURING SUDDEN COMMENCEMENT OF MAGNETIC STORMS. (The full text is in press in Publ. Crimean Obs. 1958)

by A.S. DWORJASHIN

The sharp variation of the Earth's magnetic field during sudden commencement is interpretated as a result of a passage of the shock wave /1-3/, crossing the interplanetary space and having its origin in the solar flare /4-7/ or as a result of the movement of corpuscular stream. This explanation is possible, because the density of interplanetary space /8-13/ is equal 10^2-10^3 ions/cm^3. It is difficulty to explain the sharp front into conditions of low density of interplanetary medium when the mean free path is large. The velocity of magnetohydrodynamic sound in the interplanetary space $\sim 10^6$ cm/sec., when $H \sim 10^{-5}$ gauss. The shock wave is strong. According to H.K. Sen /14/, the width of the shock front of strong shock wave is equal to several mean free path within shock. The thermal velocities of ions are comparable with macroscopical gas velocity beyond the shock front of the strong shock wave. Consequently, if the shock front is produced, the temperature beyond the shock front has a value of millions degrees. The mean free path determined by the expression /15/

$$\lambda = \frac{5\,(kT)^2}{2\sqrt{2}\,n_1 . Z^4 e^4 A_2(2)}\ ,$$

where

$$A_2(2) \simeq 4 \ln \frac{4k\,T}{n^{1/3} e^2}$$

is equal to 3.10^{15} cm., when $n_1 \sim 10^3$ ions/cm^3 and $A_2(2)$ 90. (It is assumed, that the average temperature within shock front is equal to mean arithmetical value of it initial and final values. The expression $\frac{1}{6} m_I V^2$ was substituted instead kT).

The obtained value ($\lambda = 3.10^{15}$ cm) is substantially larger than the width front, required by the duration of the sudden commencement of magnetic storm. Therefore with the assumed conditions we cannot explain the sharp jump of magnetic field

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during sudden commencement.

It can be shown, that a sharp front may be produced only when the magnetic field and finite conductivity are taken into consideration. In this case the width of shock front will be determined also by electromagnetical mechanism of dissipation. Consequently the width of the shock front may be considerably smaller than λ. The precise calculation of the width of shock front when λ is essentually larger than Larmor radius is not yet been carried out. In the simple case when conductivity of medium is isotopic /16/ the width of shock front would be many times larger than

$$\lambda^{*} = \frac{c^2}{4\pi \sigma a_1}$$

where is conductivity, $a_1 = \sqrt{\gamma \frac{p_1}{\rho_1}}$ - sound velocity.

The front of jump must be sharp, when the conductivity is large. Conductivity of interplanetary space is equal to 10^{11} el. stat. units, when $T \sim 10^3$ °K. According to S.Chapman /12/, the temperature may be assumed as high as 10^5 °K. In this case $\sigma \approx 10^{14}$ el.stat. units. The exceptionally sharp front of jump occurs in these two extreme cases- smaller 10^4 cm. Certainly if the density is low and conductivity is anisotropic the numeral value of jump would have other value. We can suppose however that the estimate obtained gives evidence in favour of sharp character of variation in the field within the jump.

The incidence of the shock wave (with velocity 1500 km/sec/ upon the ionized medium /17-19/ in the presence of geomagnetic field must cause some oscillations of the medium, which must propagate as magnetohydrodynamic waves. In this connection author examined the fine structure of variation of geomagnetic field during the sudden commencement of magnetic storms. The records of variation of the Earth's magnetic field has been analyzed. These records were obtained at Crimean Astrophysical

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Observatory by means of fluxmeter+) (Fig. 1). Excitation of short-periodic oscillations of geomagnetic field during sudden commencement was detected on the records studied (Fig.2,3,4). These oscillations are characterized by the following properties:

1. The sigh of the first oscillation is always positive and corresponds to the increase of the field.
2. The amplitude of the first oscillation as a rule is the highest. The average amplitude is equal $A \sim 0.2 \div 0.1 \gamma$.
3. The periods of oscillations are 12-15 sec.
4. The oscillations attenuate in 1-2 min
5. It is possible there is the daily (diurnal) variation of amplitude of oscillations exitated during SSC. This question would be examine later on.

Dungey /20/ was the first who paid attention to the ripples observed sometimes on the magnetogramms. The theory of magnetohydrodynamics was applied by him to explain this phenomenon. This idea was developped quickly by many investigators in the field of astrophysics. The "Pc" and "Pt" types pulsations were investigated /21-23/ . Pulsations exoitated during SSC are studied in this paper. It should be noted that is very difficult to record the oscillations during SSC because the magnetic field increases very rapidly.

The origin of a standing wave is necessary in order to periodic oscillations can occur. The path of propagation of this wave must be restricted by reflection. This reflection can occur for example when the electron density n_e increases rapidly. Knowing the period of oscillations, we can determine the wave length, which is comparable with the demensions of system. The velocity of Alfven's waves is depend on ρ . It was shown /24/, that the neutral part of the atmosphere can not take part into oscillations. Therefore the velocity of magnetohydrodynamic wave is determined only by the plasma density, that is of the ionized part of atmosphere. The neutral atoms, firstly, do not take part in the movement under consideration. The only effect

+) The more detailed description of this equipment see Annals of International Geophysical Year vol.IV,parts IV-VII p.304, 1957

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of the neutral atoms is to provide frictional resistence to movement of the ion plasma under the influence of the electromagnetic field and to transform the wave energy into heat ("frictional losses" /25-28/). Consequently, the velocity of Alfven's wave is $V \sim 2.10^8$ cm/sec., when the ionic concentration $n_i \sim 10^3$ ions/cm^3 and $H \sim 0.3$ gauss.

Taking the average period of pulsations equal to approximately 15 sec., we obtain the wave length L=V.T.= 30000 km. This means, that the oscillating system can not be restricted by fluctuations density in the ionosphere, as Dr. B.Lehnert /29/ supposed in order to explain the giant pulsations, observed in the auroral zone. The value we obtained exceeds the Earth's diameter. We conclude that the wave travels along the Earth's magnetic lines of force, which crosses the ionosphere in the geomagnetical-conjugate points. The wave reflect as soon as the line of force enters in the ionosphere. Some parts of energy can penetrate through ionosphere at every reflection causing the pulsation observed.

The dissipation of energy is caused partly by this penetration and partly by the Joule /30/ and "frictional" losses /25-28/. It is easy to show, that the Joule losses are not substantial for periods lesser than few minutes. The frictionall losses in the interplanetary space are small due to the low relatively abundance of neutral atoms. However they can be substantial for the penetrating waves, passing through the ionosphere.

The principal mechanism of impulse-transmissions from ions to the neutral atoms is the charge transfer reaction (the cross section of the elastic collision is less than the cross section of the charge transfer reaction). Therefore the time of the charge transfer reaction will determine approximately the time of dissipation of energy. The free path of ions before the charge transfer reaction $\ell \sim 10^7$ cm in the F2 layer and 2.10^5cm in the F1 layer. The small value of ℓ in F1 layer restricts the possibility of production of standung magnetohydrodynamic waves in this layer, because the time of the charge transfer reaction

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is of order to some seconds.

The attenuation of magnetohydrodynamics waves due to the interactions with neutral atoms is not substantial in the model supposed, because the most part of the wave is situated over the F2 layer. The oscillation may be maintained in the F2 layer due to the magnetic energy transmitted from the higher layers along the lines of force. Attenuation of the wave running through F1 layer could not be completed because the wave propagates with the velocity having order of magnitude $V \sim 5.10^7$ cm/sec. So the wave will intersect the layer in the time of only about 0.2 sec. During this time the oscillating, ion will pass about 2.10^4 cm, and the charge transfer reactions would not take place. As for the layer E., the time of crossing it by the wave is higher than the time of charge transfer reaction. This is a difficulty of the hypothesis proposed. This relates to any other hypothesis explaining the appearence of short-periodic oscillations.

It should be noted, that the excitation of short-periodic oscillations during SSC do not necessary require the presence of the shock wave. It is possible to explain the short-periodic oscillations by the usually considered corpuscular Chapman-Ferro stream also.

We must suppose that the corpuscular beam consists of separate corpuscular clouds. These clouds must contain a "frozen-in" magnetic field. The existence of these frozen-in magnetic fields follows from the study of cosmic ray storm variation /31-32/.

The short- periodic oscillations observed when magnetic field is disturbed (bay with pulsations) can be explained by the excitation of magnetohydrodynamic waves by the shocks of separated corpuscular "condensations", carrying a "frozen-in" magnetic fields /33/. The interactions these corpuscular "condensations" with the Earth's magnetic field was examined in /34-35/.

In conclusion the writer wishes to express his sincere thanks to S.B.Pickelner for his valuable instructions.

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